VII.17 Carbon-based Fuel Cell

Steven S. C. Chuang
Department of Chemical Engineering, The University of Akron
200 East Buchtel Commons
Akron, OH 44325-3906
Phone: (330) 972-6993; Fax: (330) 972-5856; E-mail: schuang@uakron.edu

DOE Project Manager: Travis Shultz
Phone: (304) 285-1370; Fax: (304) 285-4638; E-mail: Travis.Shultz@netl.doe.gov

Objectives

- Determine the technical feasibility of using coal as the fuel for solid oxide fuel cells.

Approach

- Develop an anode catalyst to promote the electrochemical oxidation of coal.
- Employ mass spectrometer and infrared spectrometer to monitor the effluent of the coal fuel cell.

Accomplishments

- Demonstrated that the use of coal as the fuel to the solid oxide fuel cell is technically feasible.
- Showed that the coal fuel cell gave 80 mA/cm^2 at 0.7 V.

Future Directions

- Increase the current density of the coal fuel cell above 200 mA/cm^2 at 0.7 V.

Introduction

The direct use of carbon from coal as a fuel for the solid oxide fuel cell to generate electricity is an innovative concept for power generation. This type of C-fuel cell (carbon-based fuel cell) could offer significant advantages in (i) minimization of NO_x emissions due to the operating temperature range of 700 - 1000°C, (ii) high overall efficiency because of the direct conversion of carbon to CO_2, and (iii) low investment and maintenance cost due to simplicity of the process. The objective of this study is to investigate the performance of a highly active anode catalyst for the electrochemical oxidation of coal. The performance of this C-fuel cell will be determined by measuring the voltage output and current density as a function of temperature, time, anode catalyst compositions, concentration of SO_2, and composition of carbon black and coal slurry. The results of this study will allow us to evaluate the limitations and potential of the carbon-based fuel cell for practical applications.

Approach

A number of solid oxide fuel cells were fabricated and tested at 950°C. The yttria-stabilized zirconia (YSZ) electrolyte was purchased from Tosoh Corp; its thickness is 1 mm. Both current and voltage output data from the fuel cell were acquired by a PC with an interface and Labview™ software. The gaseous product was analyzed by a SRI 8610C gas chromatograph and a Pfeiffer QMS 200 mass spectrometer. The analysis of gaseous products, such as CO and CO_2, allows determination of the fuel conversion efficiency and byproduct formation.

Results

Figure 1 shows the performance (I-V curves) of our fuel cell with a highly active oxidation catalyst using CH_4 and Ohio No. 5 coal as fuels. Ohio No. 5 coal contains 2% sulfur, 84% fixed carbon, and 5% ash. Coal was loaded on the anode side and gradually heated to 950°C. The coal fuel cell at

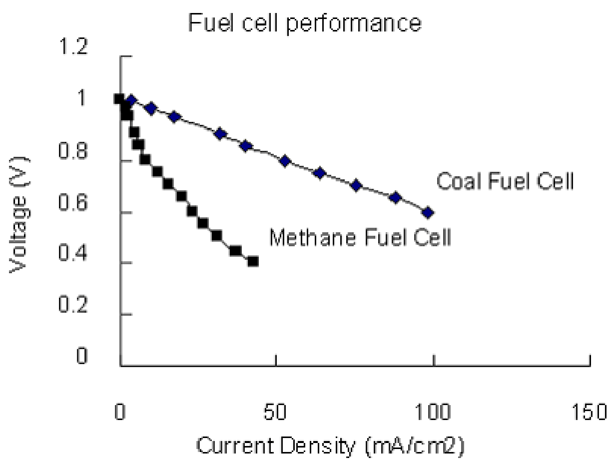

Figure 1. Fuel Cell Performance

950°C produced higher current density than did the CH_4-fuel cell. It is remarkable to observe that the current-voltage (I-V) curve for coal is higher than that for methane. Comparison of the CH_4 I-V curve in Figure 1 with those in literature (1-4) shows that the current density for CH_4 is about 35% of the best reported data for the direct methane solid oxide fuel cell. This is due to the use of thicker solid YSZ electrolyte (i.e, 1 mm in thickness) in our fuel cell as compared with 50 microns in the literature.

The analysis of the gaseous stream showed that the major product produced from the coal fuel cell is CO_2 with less than 5% of CO. CO concentration can be further decreased by decreasing the flow rate of Ar which was used to bring out the gaseous product for the analysis. SO_2 was only observed during heating of coal. SO_2 and CO, H_2 and CH_4 begin to form at 400°C. The SO_2 concentration in the fuel cell effluent reached a peak at 650°C and then declined with temperature. Repeated runs on the same fuel cell gave the same level of electric power as that in the first run.

Conclusions

- The use of coal as the fuel to the solid oxide fuel cell is technically feasible.

References

1. S. Park, J. M. Vohs, R. L. Gorte, Nature 404 (2000) 265.

2. T. Ishihara, T. Yamada, T. Akbay, Y. Takita, Chem. Eng. Sci. 54 (1999) 1535.

3. T. Horita, N. Sakai, T. Kawada, H. Yokokawa, M. Dokiya, J. Electrochem. Soc. 143 (1996) 1161.

4. S. A. Barnett in Handbook of Fuel Cells, eds: W Vielstich, A. Lamm, and H. A. Gasteiger, Wiley, 2003.

FY 2004 Publications/Presentations

1. “Coal-based Fuel Cell,” Ohio Hydrogen from Coal Forum, April 2, 2004.

Special Recognitions & Awards/Patents Issued

1. Steven S. C. Chuang and Rajesh Khatri, U.S. Patent Application 60,520,455, The University of Akron, December 2003.